

REMARKS

Reconsideration of the present patent application is respectfully requested. Claims 1-32 and 34-40 are pending in this application. By this amendment, claims 1, 30 and 40 have been amended.

Claims 1-7, 13 and 26-29 have been rejected under 35 USC § 103(a) as being unpatentable over Tournazou et al. (Electronic Letters, No. 22, Oct. 1994, pgs. 1839-1841) in view of Orban (United States Patent No. 5,168,526). Claims 1, 30 and 40, as amended, recite, in pertinent part, an analogue signal processor comprising:

“first and second log-domain filters having different low-pass bands and a subtractor for subtracting the output currents of the filters to produce a filtered signal, each of the filters comprising MOS transistors operating in weak inversion, each of the filters being tuneable in the audio-frequency range to adjust the low-pass cut-off frequency”

The starting point for the present invention is a desire to provide an analogue signal processor having a tone control circuit which allows different frequency bands of an audio signal to be independently controlled with maximum flexibility. The processor must be able to handle slowly varying, large signals such as arise in biomedical applications, e.g. hearing aids and cochlear implants.

Conventional approaches to this problem have made use of multiple bandpass filters to isolate respective frequency bands. The individual bandpass filters themselves have been implemented in a number of different ways. The most common approach is to use a biquad bandpass filter. However, this allows only adjustment of the centre frequency of the band and of Q, and therefore does not allow the upper and lower cut-off frequencies to be adjusted independently. If this is deemed necessary, one could consider arranging a low pass filter and a high pass filter in cascade (i.e. in series with one another). However, it is difficult to provide a high pass filter having the necessary stability, and this approach is not used in practice.

The inventors here have recognized that, in order to allow independent control (variability) of the high and low frequency cut-offs within each frequency band, two low-pass filters can be arranged in parallel with the output of one being subtracted from the output of the other. However, such an arrangement may not be practical if the filters operate in voltage mode,

providing voltage signals at their outputs. This is because a voltage subtractor is complex and costly to implement (e.g. in terms of silicon area), and generally requires the conversion of the voltage signals to currents, introducing non-linearities.

A further significant aspect of the invention therefore is the use of log domain filters as the low pass filters (log domain filters by their very nature operate in current mode), and the provision of a subtractor which subtracts the current outputs of the log domain filters. In practice the subtractor is extremely simple to implement, indeed it might be merely a point connecting the two output lines together, and will not introduce any non-linearities into the signal processing operation. Moreover, log-domain filters are ideally suited to large signal applications due to the compression of the input signal and expansion of the output signal which is inherent in log domain filter operation.

Insofar as tone control circuits are concerned, the claimed invention provides a truly novel and inventive audio signal processing architecture.

Considering Toumazou, this paper teaches a cascaded low-pass filter architecture, where each low-pass filter is provided by a biquad lowpass filter. This circuit does not allow for flexible tone control, as each "band" into which the signal is split has only a low cut-off frequency and no high cut-off frequency. Moreover, Toumazou does not teach a mechanism for tuning even the low frequency cut-off of each filter stage. The skilled person would have had no motivation to modify the architecture described in that document to provide for independent adjustment of the high and low-pass cut-off frequencies (i.e. tone control). However, even if he had recognized that such modification was desirable, there is nothing in Toumazou or in the other known prior art to lead the skilled person to firstly consider using bandpass filters to separate the audio signal into discrete frequency bands, and secondly to form each bandpass filter using a pair of low pass filters in parallel. The former is quite contrary to the teaching of Toumazou which requires the cascading of filter stages, whilst the latter is contrary to all conventional approaches which use either a biquad filter or a low-pass/high pass cascade arrangement to implement a bandpass filter.

In attempting to provide for adjustment of the high and low-pass cut-off frequencies of each frequency band of the audio signal, the skilled person aware of Toumazou would have had

no motivation to look to Orban (US4,525,857). This document is concerned with providing an audio peak limiter which minimizes signal distortion. Orban is wholly unrelated to the problem of providing flexible tone control.

Applicants submit that it is unreasonable to select a small portion of the highly complex circuit of Orban to support a rejection of the present invention. The bandpass filter (42) of Orban does not perform any tone control function within the overall circuit of Orban. Moreover, it is stated at column 6, line 64 to column 7, line 29 of Orban that the filter (42) need only be a high-pass filter in order to eliminate low frequency intermodulation (IM) distortion introduced by the voltage controlled amplifier (30). A bandpass filter is only used because bandwidth limitation is desirable for broadcast or communication applications. To repeat, the bandpass filter of Orban is used to eliminate low frequency intermodulation distortion and does not provide for any tone control of the audio signal.

Orban does not disclose any means for adjusting the high and low-frequency cut-offs of the bandpass filter (42). This is of course not surprising as these values will be determined and fixed by the properties of the circuit itself, and in particular of the voltage controlled amplifier (30), and of the application (broadcasting), and are not determined by either the audio signal itself or the (hearing) preferences of a user.

It is further submitted that the skilled person, even if he had known of Orban, would have dismissed Orban as being irrelevant to the teaching of Toumazou. There is nothing in Orban to suggest that the circuit described therein, and in particular the bandpass filter, operates in the current mode. Given that voltage mode is the conventional operating mode for such circuits, the skilled person would have dismissed Orban as describing a voltage mode circuit which is incompatible with the current mode circuit of Toumazou. The circuit of Orban when viewed as a whole, or considering only the bandpass filter arrangement, is useable only for small signal operation and is therefore not applicable to biomedical type applications where input and output signals are often slowly varying, large signals. In summary, Orban is concerned with voltage mode, small signal applications, whilst Toumazou is concerned with current mode, large signal applications.

Claims 30, 31, 34 and 36 were rejected under 35 USC §103(a) as being unpatentable over Michelson (US Patent No. 4,400,590) in view of Toumazou et al. For the following reasons Applicants respectfully request reconsideration of this rejection.

It is further submitted that the amendments and arguments made above make the rejections based on the combination of Michelson and Toumazou et al. moot. As stated in the Office Action, Michelson does not disclose the use of log-domain filters or MOS transistors operating in weak inversion. Since Toumazou does not teach or suggest that each of the filters are tuneable in the audio-frequency range to adjust the low-pass cut-off frequency, as stated above, the combination of Michelson and Toumazou does not teach or suggest the rejected claims. Reconsideration is respectfully requested.


While Claim 40 was not specifically rejected in the Office Action, Applicants believe that the arguments made above apply to Claim 40, as amended, and thus Claim 40 is not rendered unpatentable in view of Toumazou, Michelson, Orban or any combination thereof.

Conclusion:

Based on the foregoing remarks and amendments, Applicants believe that all of the claims in this case are now in condition for allowance and an indication to that effect is respectfully requested. Furthermore, if the Examiner believes that additional discussions or information might advance the prosecution of this case, the Examiner should feel free to contact the undersigned at the telephone number indicated below.

Respectfully submitted,

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By: 
Douglas B. McKnight, Reg. No. 50,447
(216) 622-8559